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Research paper

Effect of Adding RON97 Into Waste Cooking Oil as an Alternative Fuel for Diesel Engine

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Abstract

Petroleum-based fuel reserves are drastically depleting due to a high demand on sustaining a better lifestyle. This paper presents the utilization of waste cooking oil (WCO) as an alternative fuel for diesel engine. Although WCO and conventional diesel fuel have similar physiochemical properties, the properties of WCO is considered inferior than conventional diesel fuel. It is due to higher viscosity and density of WCO while its calorific value is lower than conventional diesel fuel. In this research, unmodified WCO was blended with petrol fuel grade RON97. Five blended fuels samples were prepared from five to 25 percent volume base with five percent step increment. The density and calorific value of all fuel blend samples together with unmodified WCO were measured and compared to the conventional diesel and RON97 fuels. Each of the blended fuel and conventional diesel were used to run a single cylinder diesel engine. The performance characteristic of the engine was recorded at different engine speeds ranging between 1500 and 3000 rpm. Results showed that the properties of blended fuel were inferior compared to the conventional diesel fuel; however, by adding 15 percent of RON97 into the unmodified WCO, the results were comparable to the conventional diesel fuel.

Keywords: *Alternative fuel; diesel engine; waste cooking oil; blended fuel.*

1. Introduction

Increase in energy demand and depletion of petroleum-based fuel resources have led the researchers to find alternative fuels for internal combustion engines [1]. Since waste cooking oil (WCO) has similar physiochemical properties as conventional diesel fuel, WCO can be used as an alternative for conventional diesel fuel [2]. The waste cooking oil is an economical resource and can be easily obtained from various resources such as household and fast food restaurant [3]. However, irresponsible dumping of WCO in the drain is posing a serious disposal problem. As such, by utilizing WCO as an alternative fuel for diesel engine, it could potentially reduce the burden on the dependency of petroleum-based fuel as well as reducing its disposal problem [4].

The quality of WCO is reduced when it undergoes physical and chemical changes during an infinite number of frying. This may cause an improper compression ignition (CI) engine combustion and lead to an improper performance of the engine. Due to this problem, many researchers converted the WCO into biodiesel by using the transesterification process [5]. From the literature, the results of converting WCO to biodiesel showed a significant improvement in which the biodiesel based on WCO could directly be used as a substitute to the conventional diesel fuel without major modification to the current diesel engine itself.

Another method to solve the problem of low quality WCO is by blending it with a secondary and relatively high-quality fuel such as conventional diesel itself or by adding an additive to the WCO [3]. This method is considered as the simplest method where it can be accomplished by using a splash mixture where the two fuels are poured into a container and gently stirred so that they can homogenously blend together. This is because in general, WCO has similar physiochemical properties as petroleum-based fuel.

In this research, the blending method is used to improve the quality of WCO after considering its simplicity as mentioned above. As for the secondary fuel, this research used petrol fuel grade RON97. The selection of RON97 is motivated by its higher volatility and lower density than WCO. Hypothetically, a higher volatility of RON97 will increase the volatility of the WCO while a lower density of RON97 will reduce the density of the WCO. This condition is expected to increase the evaporations and diffusions of the fuels mix during fuel injection period and stimulate the combustion process. However, this research is aware that the RON97 and WCO that were used for the conventional diesel fuel substitutes were rated by octane and cetane number, respectively [6] and they are contradicting to each other. However, since this blending combination (RON97 and WCO) is considered as a preliminary study, this research has limited the study to only observe and investigate whether or not they can be blended together and run on a diesel engine. The effects of octane and cetane number to the performance and emissions will be included in the future research work based on the results of this research.

In doing so, the optimized blending ratio between WCO and RON97 needs to be determined. Hence, this research added five to 25 percent volume based of RON97 into an unmodified filtered WCO with five percent step volume base. Afterwards, the fuel properties of density and calorific value were measured together with an unmodified filtered WCO and the conventional fuel that will be made as a base result. After that, the conventional diesel fuel together with all fuel blends of WCO and RON97 are used to run on a single cylinder research engine. The results of the engine performance are measured, calculated and analyzed to investigate the effect of these fuels mixing before the conclusion of blending WCO and RON97 can be made.

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The details on the methodology of fuels properties measurement, experimental setup as well as the results from this research are explained in the following sections.

2. Method

In this research work, the methodology can be divided into two parts. The first part is for fuel sample preparation and the second part is the engine testing or performance test on the engine itself.
As for the fuel sample preparation, the WCO was collected from a single local cafeteria that used palm oil to fry various types of food products such as chicken, potatoes and banana fritters. This would mean that the WCO was obtained from palm oil, which was being used to fry uncontrolled type of product. The WCO was then filtered using a nylon mesh filter to remove debris and other unwanted particles. As for the RON97 and conventional diesel fuels, they were bought from a local petrol station. The RON97 was added into the WCO according to volume base of five to 25 percent with a step increment of five percent, respectively, to make a total of five fuel blended samples denoted as W95R05, W90R10, W85R15, W80R20 and W75R25, i.e. W for WCO and R for RON97. Each of the fuel sample was stirred by using a hot-plate stirring machine, which was rotated at 400 rpm for 10 minutes to ensure that they were properly blended. Afterwards, a sample of 140 mL of each of the fuel blend along with the WCO, conventional diesel fuel and RON97 were weighted on an analytical balance machine for density determination. Additionally, a boom calorimeter was used to measure the energy content in terms of calorific values for each of the fuel blended sample, WCO, conventional diesel fuel and RON97.
Upon completion of the fuel samples preparation, the research engine was set up. In this research, a Robin model DY23-2D diesel engine was used. The engine is a single cylinder, 230 cc, air cooled that could produce a maximum power of 4.8 kW. The schematic diagram of the engine testing is illustrated in Fig. 1. Based on the figure, the fuel tank system was modified where another tank was added into the system and controlled by means of a control valve. This arrangement was used to allow the selection of conventional diesel fuel in one of the tanks and the other tank was used for fuel blended samples. The other setup was a standard setup of engine coupled with an electric dynamometer [7]. In the experimental procedure, the engine was first run with the conventional diesel fuel. After reaching the engine operating temperature at idling speed by monitoring the exhaust temperature, the engine was loaded at 2 N and the throttle was increased to increase the engine speed to 1500 rpm. The required data for engine performance were then recorded. Afterwards, the engine speed was again increased by 250 rpm to 1750 rpm and similar required data were recorded. These steps were repeated until the engine speed reached 3000 rpm. Upon completion on this set of experiment, the engine speed was brought down to idling speed and the load was released. Then, the fuel was switched to the fuel blended samples starting with W95R05 sample. Similar procedure as per conventional diesel fuel was repeated. After finishing the sample of W95R05, the fuel was changed back to the conventional diesel to flush the W95R05 fuel before W90R10 was used. These procedures were repeated for all fuel samples and the whole experiments were conducted in one run. Conducting the experiment in one run was to avoid different surrounding conditions of the experiment that could affect the experimental results. Since this preliminary study was to observe and investigate the workability of these fuel blends, the experiment was done with one run for each fuel sample.

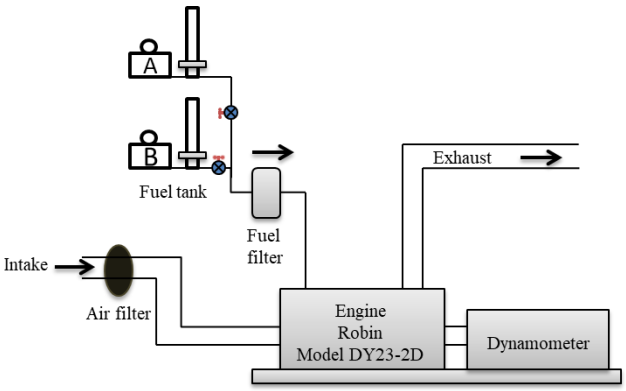


Fig. 1: Schematic diagram of engine dynamometer with dual fuel tanks

3. Results and Discussion

The results of density for all fuel samples are illustrated in Fig. 2. Based on the figure, the highest density was recorded by WCO and the lowest density was recorded by RON97. This result supported the aim of this research where a low volatile WCO was mixed with a higher volatile RON97 to improve the WCO properties. The result on the fuel mixing also showed an expected result in which when the amount of RON97 added into WCO was increased, the density was gradually reduced.
Fig. 3 shows the results of calorific value of the fuel samples. According to Fig. 3, the highest calorific value was recorded by conventional diesel fuel as expected and the lowest calorific value was recorded by WCO. When the fuel was mixed, the calorific value increased as the volume of RON97 was increased. This trend can be considered as a normal trend since RON97 has a higher calorific value than WCO.
The results of density and calorific values presented in Fig. 2 and Fig. 3 proved that adding volatile fuel into WCO could reduce the density and increase the calorific value of the fuel blends.
Fig. 4 shows the results of engine power versus engine speed for all fuel types. The trend in Fig. 4 showed that the engine power increased linearly as engine speed was increased. This trend matched the theory since the engine power is a function of engine load and engine speed [8]. In the experiment, the engine load was constantly set at 2 N throughout the experiment and the engine speed was increased linearly.
The result of fuel mass flow rate versus engine speed is illustrated in Fig. 5. According to the figure, the fuel mass flow rate was increased as the engine speed was increased. This trend is typical since at a higher engine speed, more power is required, and more fuel is needed [9]. Fig. 5 also shows that the lowest fuel mass flow rate was recorded by the conventional diesel fuel for each recorded engine speed. This result is expected due to the lower density and higher calorific value of conventional diesel fuel as compared to the blended fuels as shown above. Interestingly, at a lower engine speed, lower fuel mass flow rates among fuel blends were recorded by W85R15 and W75R25, which are in the category of higher proportions of RON97 in the fuel blends. At a higher engine speed, the lowest fuel mass flow rate among fuel blends was recorded by W90R10, which is in the category of a lower proportion of RON97. This result is expected since at a lower engine speed, a higher volatile fuel blend helps the combustion; therefore, it needs a smaller amount of fuel to convert into power. However, at a higher engine speed, the engine operating temperature is high enough to reduce the viscosity of the fuel, and the oxygen content in the fuel molecules can easily escape from the molecular chain and help the combustion process [10]. Additionally, the proportion of WCO is higher in W90R10, which relatively has a higher oxygen content than W85R15 and W75R25. The presence of oxygen content in the molecular chain of the vegetable oils helps the combustion process as acknowledged by many researchers and this research also proves the contribution of the oxygen content [11, 12].

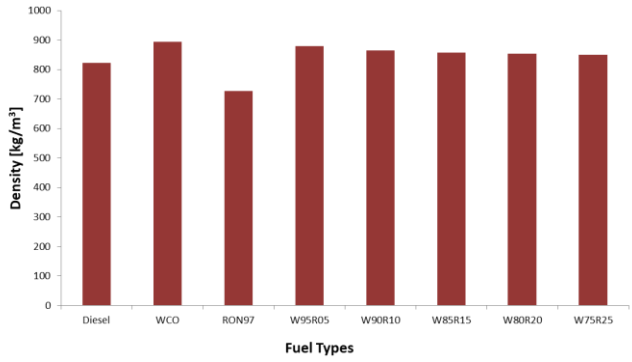


Fig. 2: The density of all fuel samples

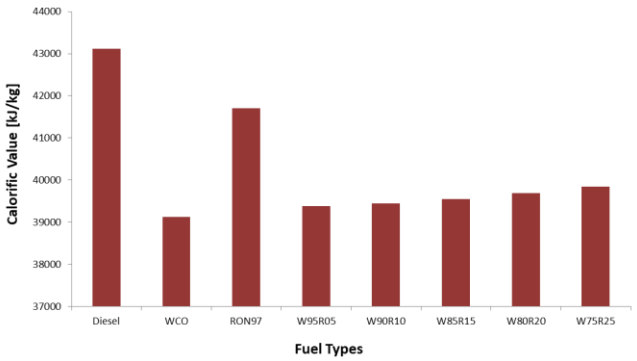


Fig. 3: The calorific value of all fuel samples.

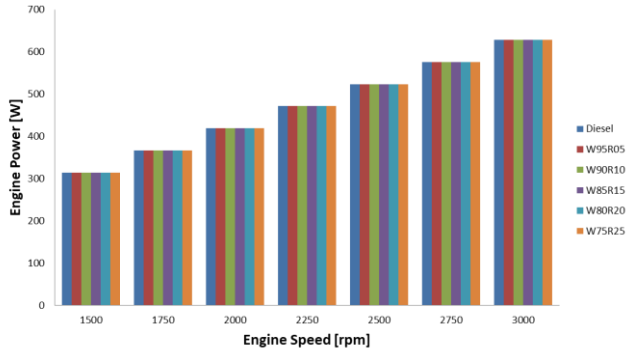


Fig. 4: The engine power versus engine speed for all runs of various fuel samples.

Fig. 6 shows the results of brake specific fuel consumptions (BSFC) for all runs of all fuel samples. The trend shown in Fig. 6 can be considered as a typical trend of BSFC where the BSCF was gradually reduced from a lower engine speed into an engine rated speed and then increased as the engine speed was ramped up [13]. Based on that, this research estimated that the engine rated speed for this engine was between 2000 and 2500 rpm. The trend of the results shown in this figure was comparable to the fuel mass flow rate where the lowest BSCF belonged to the conventional diesel fuel since the measurement of BSFC was based on the results of fuel mass flow rate. As the lowest fuel mass flow rate at a lower engine speed was achieved by W85R15 and W25R75 while the lowest fuel mass flow rate at a higher engine speed belonged to W90R10, the results of BSFC were also similar. However, at a rated engine speed (between 2000 and 2500 rpm), the lowest BSFC was recorded by W75R25 since it recorded the lowest BSFC at 2000 and 2250 rpm while the second lowest was W85R15 blended fuel at 2500 rpm.

The result of engine efficiency is illustrated in Fig. 7. The trend shown in the figure is a typical trend of an engine efficiency where the efficiency increased until engine rated speed and decreased afterwards [14]. Based on the figure, the highest engine efficiency between 1500 and 2250 rpm was recorded by W75R25, i.e. the highest proportion of RON97 in the fuel mixture. Beyond, 2250 rpm, the highest engine efficiency was recorded by the conventional diesel fuel run. This condition shows that the oxygen content in WCO molecular chain mixed well with the higher volatile RON97, which resulted in a higher engine efficiency. Additionally, since the denominator to calculate the engine efficiency is the calorific value where the calorific value of W75R25 is lower than the conventional diesel fuel, the engine efficiency is higher. However, at a higher engine speed of 300 rpm, the engine efficiency for W75R25 was the lowest. This condition is expected since the volatility of the fuel blend at this ratio is not suitable due to the high volatile RON97.

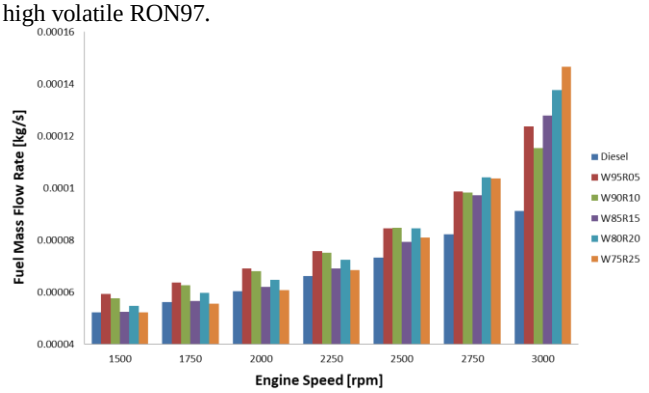


Fig. 5: The fuel mass flow rate versus engine speed for all runs of various fuel samples.

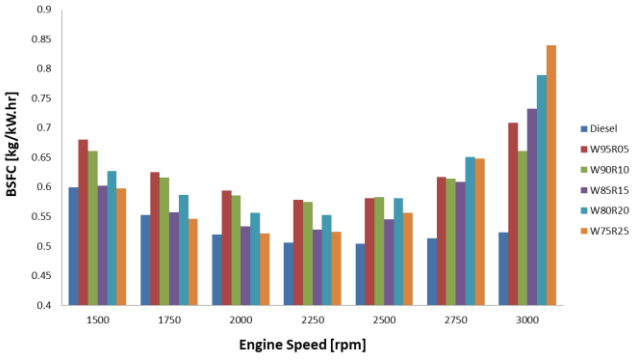


Fig. 6: The BSFC versus engine speed for all runs of various fuel samples.

Based on the results presented, this research acknowledges that the blended fuel between WCO and RON97 is not suitable to be used in a dynamics engine, i.e. automotive engine, for the current condition. This is because the results were not consistent where none of the blended fuels produced better results for all engine performance parameters. Therefore, this research recommended a further study to be conducted to solve the inconsistent dynamics running of the diesel engine with this blending technique. However, this research acknowledges that this method is more suitable to be used for a stationary engine such as gen-set where it is running at a constant engine speed. For a stationary engine, this research suggests that W75R25 blend is the best since it produced better results for BSFC and engine efficiency at rated engine speed.

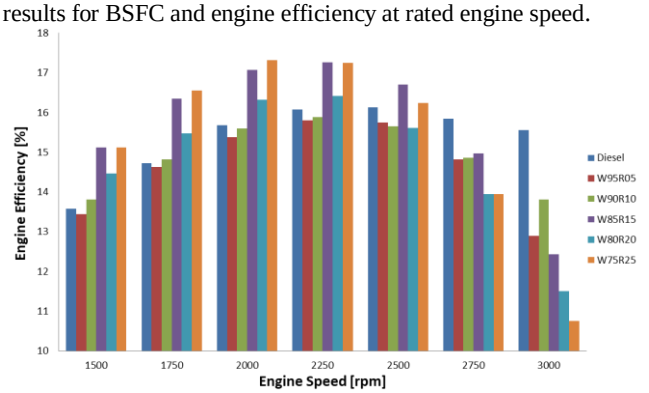


Fig. 7: The engine efficiency versus engine speed for all runs of various fuel samples

4. Conclusion and Recommendations

This project investigated the effect of blending WCO and RON97 as an alternative fuel for the conventional diesel fuel run in a diesel engine as well as their optimum blending ratio. The WCO was collected from a nearby local cafeteria and was filtered accordingly before blending it with RON97 at certain proportions. The fuel properties of all samples were then measured. After that, each fuel samples including conventional diesel fuel were used to run a single cylinder diesel engine coupled with an electric dynamometer. Based on the observation during experimental work, the CI engine ran without any problems with these blended fuels. The engine performance parameters were then calculated. Based on the experimental results, this research acknowledges that the method of blending unmodified WCO and RON97 is not suitable to be used on a dynamics engine (at various engine speeds and loads) since none of the results were superior for a single mixture. On the other hand, this research acknowledges that this method is suitable for a stationary engine that runs constantly at rated speed between 2000 and 2500 rpm while the optimized blending ratio was 25 percent volume of RON97 base to 75 percent volume of WCO base. Furthermore, this research recommends investigating the effect of octane-cetane relationship on the CI engine performance as well as other fuel properties such as volatility, cetane number and others.

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